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Guidelines for Preventing Fire Retardant Corrosion

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Cover—Examples of corrosion of tanks, aircraft, mixing, transfer and storage equipment caused by forest fire retardants.

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AUTHORS

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CHARLES W. GEORGE received his B.S. degree in forest engineering in 1964 and M.S. degree in forestry in 1969. He joined Intermountain Station's staff in 1965 where he has conducted studies related to prescribed fire, pyrolysis and combustion, fire retardants and aerial delivery systems. Presently Mr. George is project leader of the Fire Suppression research work unit at the Intermountain Fire Sciences Laboratory (formerly Northern Forest Fire Laboratory). The current mission of the work unit is to develop the knowledge and application systems needed to improve fire control capabilities, to reduce costs, and to improve chemical fire suppression technology.

RESEARCH SUMMARY

Fire control agencies in the United States use millions of gallons of fire retardant annually in the suppression of wildfires. Most of the fire retardants now in use are chemical salt solutions (usually 10 to 15 percent) of monammonium phosphate, diammonium phosphate, ammonium polyphosphate, or ammonium sulfate. The chemical salt solutions used as fire retardants corrode metal. This corrosion can destroy the equipment used for mixing, storing, and applying fire retardants, resulting in a loss of hundreds of thousands of dollars of equipment every fire season. In addition to the economic loss, corrosion of equipment, particularly aircraft can create safety hazards.

The purpose of these guidelines is to help those who operate and maintain airtankers and ground support equipment to fight corrosion. These guidelines describe the corrosive action of fire retardants and tell how to control or minimize corrosion of airtankers and ground support equipment.

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INTRODUCTION

Fire retardants can cause corrosion that can wreck pumps, chew holes in tanks and piping, and raise havoc with airplanes. Although Forest Service-approved fire retardants contain corrosion inhibitors to minimize corrosion, corrosion is still a possibility no matter what retardant you use, and some retardants may cause more trouble than others.

Fire retardant corrosion can be controlled. Knowing the basic facts about corrosion helps one understand what must be done to control it. There follows a nontechnical discussion of reasons for preventing corrosion, how corrosion occurs, the type of corrosion caused by fire retardants, and factors that affect corrosion rate.

REASONS FOR PREVENTING CORROSION

Safety

A corroded part can be a safety hazard. Corrosion can weaken a part so it no longer has the strength to do what it was designed to do. Corrosion damage is not always obvious without careful inspection. A critical part such as a landing gear strut, wheel treadle, or control cable could fail suddenly. Such failures could cause or result in a serious accident and injury.

Loss of Mission

Corrosion can seriously impair system reliability resulting in loss of mission—the ability to deliver fire retardant where and when it is needed. A faulty pump, defective valve, broken hydraulic lines, or broken actuators could impede firefighting efforts at a critical moment.

Cost

Replacing parts destroyed by corrosion can be costly, particularly when preventive maintenance could have extended the life of the part. Cost of part replacement includes the cost of the part; the cost of labor involved in disassembly, installation, and reassembly; and cost of down time. If an aircraft or the mixing plant is shut down during a fire, the cost of the additional fire damage must also be included.

Appearance

A rusty mixing tank or corroded fuselage does nothing to impart pride or confidence in the equipment.

CORROSION IN GENERAL

Corrosion - How it Occurs

Corrosion requires four ingredients:

1. an anode
2. a cathode
3. an electrolyte
4. an electrical connection between the anode and cathode.

Removing any single ingredient stops corrosion. Reducing the effectiveness of any one ingredient, or combination of ingredients, reduces corrosion. Keep this in mind while we define each ingredient.

1. Anode: This is the place on the metal that corrodes.
2. Cathode: This is the place on the metal that does not corrode.
3. Electrolyte: This is the electrically conductive fluid with which the anode and cathode must be in contact—usually it is water containing dissolved solids. Fire retardant solutions are electrolytes.
4. Electrical connection: The anode and cathode must be electrically connected. If the anode and cathode are on the surface of the same metal, the metal itself serves as the electrical connection. If the anode and cathode are two different pieces of metal, they must touch each other or be connected by another piece of metal.

When all four ingredients exist at the same time, this is what happens:

-The anode corrodes.

-The cathode does not corrode.

-An electrical current flows between the anode and cathode. This current flows from the anode to the cathode through the electrolyte then flows from the cathode to the anode over the electrical connection, completing the circuit. The greater the current, the faster the corrosion.

Types of Corrosion

Fire retardants primarily cause two types of corrosion:

1. *Galvanic corrosion.*—This type of corrosion involves at least two different metals. One is the anode—it corrodes; the other is the cathode—it does not corrode, or at least it corrodes more slowly than the anode. Figure 1 illustrates this situation.
2. *Chemical corrosion.*—Chemical corrosion, also referred to as "local action corrosion" involves only one metal. Point-to-point differences on the metal surface become small anodes and cathodes. This often can be seen as one or more pits, a more generalized corrosion over a large surface (uniform corrosion), or a combination of these. Figure 2 illustrates this situation.

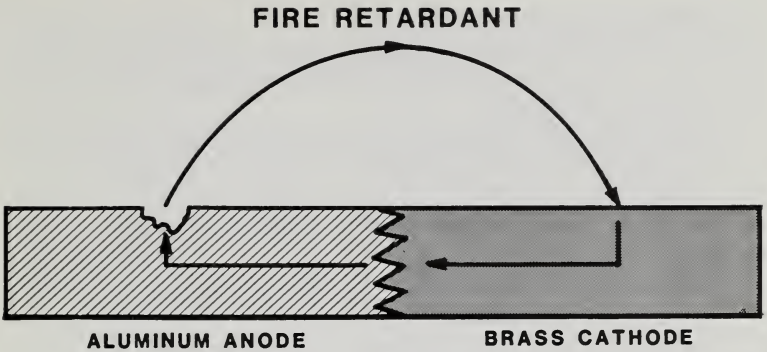


Figure 1.—Galvanic corrosion of dissimilar metals; arrows indicate corrosive attack.

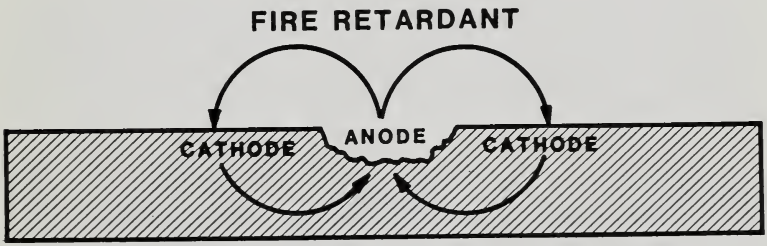


Figure 2.—Chemical or local action corrosion resulting from exposure to a fire retardant.

Both galvanic and local action corrosion can occur at the same time. Two metals may be connected, one being the anode, the other the cathode. One or both of the metal surfaces may have local anodes and cathodes. Even if the two metals are no longer connected, one, or both, may continue corroding because of local surface action.

The Rate of Corrosion

The rate of corrosion depends upon how much current flows. Current flow, in turn, depends upon:

1. The magnitude of the difference between the anode and cathode.
2. The strength or chemical activity of the electrolyte. Usually the higher the chemical activity, the higher the local action corrosion.
3. How well the electrolyte and electrical connection conduct current. The better the conductor, the higher the galvanic corrosion. (Stronger chemical activity generally goes hand-in-hand with better conductivity, so high local action corrosion and high galvanic corrosion generally go together.)

Controlling Corrosion

Corrosion control depends upon eliminating, or reducing the importance of, one or more of the four essential ingredients. Here are some basic methods of control:

1. Change materials. Substitute a corrosion-resistant material, plastic, for example. This is frequently the easiest and cheapest way to stop corrosion.
2. Use coatings. Prevent the metal from being in contact with the electrolyte.
3. Eliminate the electrolyte. There is not much that can be done to eliminate exposure of equipment and aircraft to fire retardant.
4. Change the electrolyte. The corrosivity of the electrolyte can sometimes be reduced by changing its chemistry. Usually, this is not practical in the field. Most fire retardants currently in use are chemically formulated to minimize corrosion.
5. Eliminate the electrical connection. Galvanic corrosion can be stopped by eliminating the electrical connection between two different metals. One must ensure that there is not more than one such connection. A second, less obvious connection might allow the corrosion to continue.

Summary

The preceding introduction to fire retardant corrosion shows that four ingredients are required for corrosion—anode, cathode, electrolyte, and an electrical connection between anode and cathode. Corrosion can be stopped, or at least reduced, by eliminating any one of these ingredients. The methods most frequently used for controlling corrosion were presented. The choice of method depends upon each particular situation.

CORROSION CAUSED BY FIRE RETARDANTS

General

This section is based on the results of field and laboratory investigations of the corrosion behavior of metals exposed to fire retardants. These studies showed that the extent and severity of corrosion depend upon the material of which a part is constructed, together with the nature and duration of the part's exposure. This section tells how to identify the forms of corrosion that commonly affect equipment for handling fire retardant. This manual primarily addresses the corrosion behavior of metal alloys used in airtankers and mixing equipment. These alloys and their common applications are:

Metal Alloy	Application
Aluminum 2024-T3	Aircraft tanks and gates
Aluminum 2024-T3, Alclad	Aircraft skin
Aluminum 6061-T6	Aircraft tanks and gates
Aluminum 7075-T6	Aircraft structural members

Steel AISI 4130	Aircraft torque tubes and wheel treadles
Galvanized steel	Aircraft control cables
Type 304 stainless steel	Control cables, gate hinges, pins, torque tubes, and fasteners
Type 410 stainless steel	Aircraft fasteners and control cables
Copper alloys	Valves, pipe and tank fittings, turnbuckles, and cable clamps
Magnesium	Aircraft wheel rims, hydraulic cylinder heads, and numerous helicopter components

Conditions of Exposure

A part is typically exposed to fire retardant under one or more of four different conditions: (1) continuous total immersion, (2) partial immersion, (3) alternate immersion, or (4) vapor exposure. Figure 3 shows that the internal surfaces of a tank can be exposed, at different locations, to all four conditions.

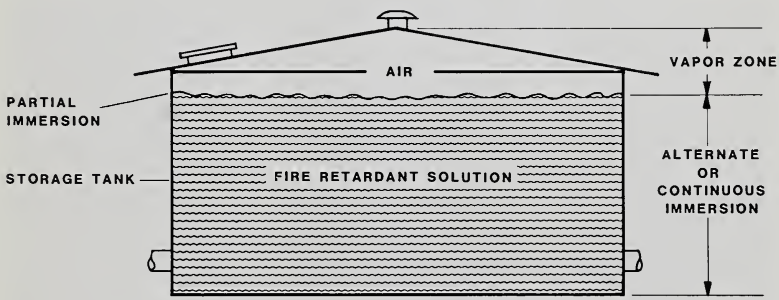


Figure 3.—Four common examples of metal-retardant exposure that can result in corrosion.

Continuous Immersion.—During this type of exposure a part is totally submerged in fire retardant all or most of the time. Storage tank bottoms and aircraft tanks in which the retardant sits for long periods of time experience this type of exposure. The general corrosion rate of an alloy under continuous immersion depends on the corrosion resistance characteristics of the specific alloy, the corrosivity of the specific fire retardant, and environmental factors such as temperature, flow rate, degree of agitation, and turbulence of the fire retardant.

Partial Immersion.—This condition exists at liquid/vapor boundaries. Such boundaries exist in partially filled aircraft tanks and ground storage tanks. Field observations, as well as laboratory studies, show

that the most severe retardant corrosion generally occurs near such liquid/vapor interfaces. Figure 4 shows an example of corrosion near the liquid/vapor interface on laboratory test specimens and a valve partially exposed to retardant.

Field observations show that the next worst corrosion occurs on tank walls and covers above the liquid/vapor interface. Condensate on these surfaces absorbs corrosive constituents from the vapor phase, forming a corrosive fluid that attacks the tank walls.

Alternate Immersion.—The most common kind of exposure is alternate exposure to fire retardant and exposure to air or vapor. This type of exposure affects mixing tanks, valves, aircraft tanks, control cables, landing gear, fuselages, and structural members. Laboratory

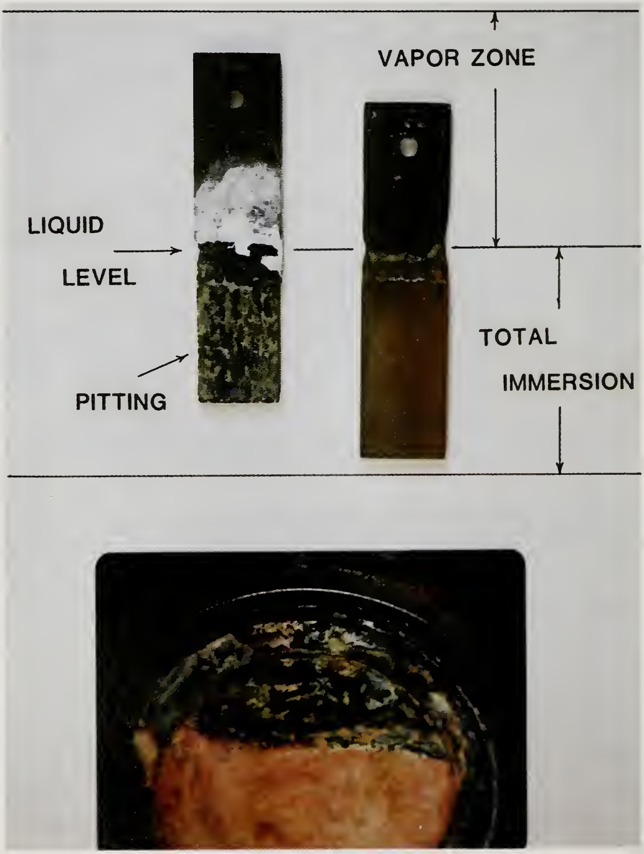


Figure 4.—Corrosion of partially immersed laboratory specimens (above) and a valve exposed partially to retardant (below).

tests showed that fire retardant usually corrodes steel and copper alloys more rapidly under alternate immersion conditions than under continuous immersion conditions.

Vapor Exposure.—Retardant vapors are often trapped in poorly vented tanks and other areas where retardant is stored. Field and laboratory studies showed that vapors from ammonium sulfate corrode steel alloys at significant rates.

Different Types of Corrosion Damage

Uniform Corrosion.—Local action corrosion that occurs uniformly over large areas of a metal surface is usually called uniform or general corrosion. The rusting of steel mixing tanks and pump (figs. 5 and 6), steel storage tanks (fig. 7), blue coloring of brass fittings (fig. 8), and deterioration of aircraft tank fittings all illustrate this type of corrosion. Corrosion of this type occurs between small anodic and cathodic areas on the metal surface as illustrated earlier in figure 2.

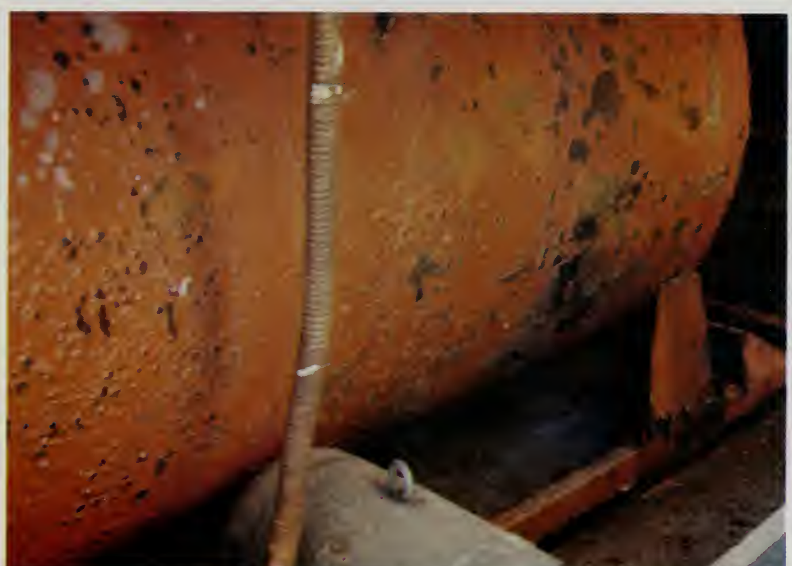


Figure 5.—General corrosion on a mixing tank.

Figure 6.—General corrosion on a transfer pump.

Figure 7.—General corrosion at a storage tank seam.

Figure 8.—General corrosion of a brass hose coupling.

Fire retardants usually corrode metals in a uniform manner. This corrosion causes seizing problems on components such as tank gate adjusting mechanisms that use threaded fasteners, steel torque tubes in the gate opening mechanism, and hinges.

Localized Corrosion.—Local action corrosion sometimes occurs on only isolated or localized areas. Those forms discussed here are: (1) pitting and (2) exfoliation.

1. *Pitting corrosion.*—This type of localized corrosion forms cavities extending directly into the metal. These cavities appear as small craters or pits on the metal surface. There may be individual pits at random locations, or groups of pits concentrated in small areas. Pitting can cause early failure of a part by perforating its wall even though the general surface is only lightly corroded. Pitting can also create stress concentrations that may contribute to or aggravate stress-corrosion cracking or fatigue.

Figure 9 shows an example of pitting on a magnesium hydraulic cylinder head. There are circumstances under which all of the materials listed previously will pit in fire retardant. Pitting is most often observed at the vapor/retardant interface. Components such as tanks, fuselages, hydraulic tubes, and tank gates on aircraft are subject to pitting. Fire retardants can cause severe pitting of magnesium aircraft wheels. The pitting of a magnesium wheel on an airtanker is shown in figure 10.

Figure 9.—Pitting corrosion of a magnesium hydraulic cylinder head.

Figure 10.—Pitting corrosion on magnesium wheel of airtanker.

2. *Exfoliation.*—Another form of localized corrosion usually affects only aluminum alloys. Corrosion of aluminum grain boundaries causes surface flaking or layering as shown in figure 11. This type of corrosion is called exfoliation. Exfoliation under paint films causes paint blistering. This type of corrosion has been observed on aluminum tank gates, fuselages, and wings.

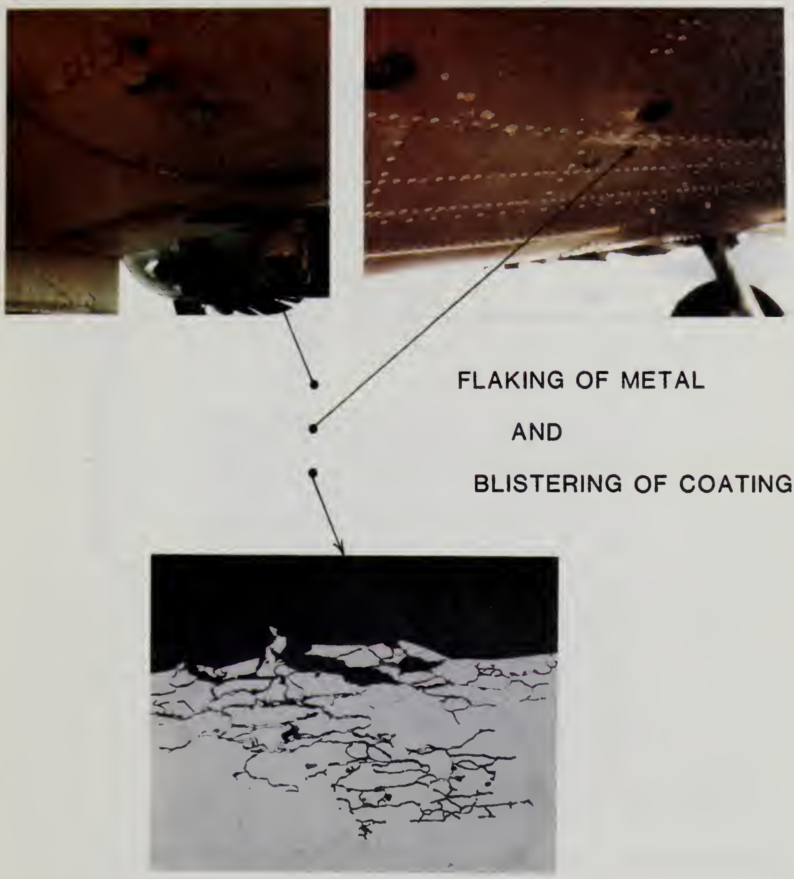


Figure 11.—Exfoliation corrosion on a fuselage.

Corrosion in Combination With a Mechanical Load.—Corrosion in the presence of a mechanical stress can cause cracking of a structural member. This type of corrosion can lead to unexpected and catastrophic failures. Cracking under a sustained tensile load in the presence of a corrodent is called stress-corrosion cracking. Welding or other manufacturing procedures frequently cause unrelieved stresses that in turn cause stress-corrosion cracking. When a cyclic load in combination with a corrosive environment causes crack growth, the phenomenon is called corrosion fatigue.

Stress-corrosion cracks usually occur near a point of stress (for example, rivet, bolt, or weld; see fig. 12). All of the alloys listed previously, with the exception of type 304 stainless steel, can develop stress-corrosion cracks when submerged in fire retardant. These alloys, however, seldom fail by stress-corrosion cracking because the actual components are designed to operate at loads well below the levels where stress-corrosion cracking normally occurs.

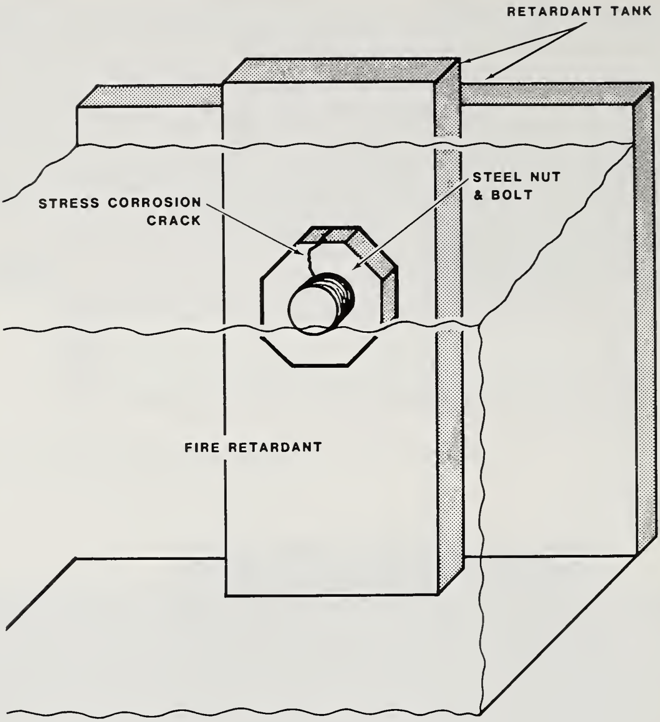


Figure 12.—Stress-corrosion crack in a steel nut in a tank exposed to fire retardant.

Corrosion fatigue, like stress-corrosion cracking, also starts near points of stress. Alloys commonly used in airtanker construction are susceptible to corrosion fatigue when exposed to fire retardant. Cyclic loads affect airtanker components such as fuselage plates, rivets, longerons, and landing gear. This can cause corrosion fatigue failure. Figure 13 shows the general appearance of corrosion fatigue cracks.

Galvanic Corrosion.—Galvanic (dissimilar metal) corrosion occurs when two or more different metals make contact with each other and an electrolyte. One metal, the cathode, is protected while the other metal, the anode, corrodes. Figure 14 illustrates a situation in which dissimilar metal corrosion might be expected. The rate of corrosion depends on the metals involved, the electrolyte, and the relative areas of the anode and cathode. Small areas of anodic metal coupled to large areas of cathodic metal lead to rapid corrosion of the anodic metal. Large areas of anodic metal coupled to small areas of cathodic metal generally do not corrode rapidly. Galvanic corrosion can occur simultaneously with general corrosion. The effects are additive. An aluminum hose fitting coupled to a brass hose fitting galvanically corrodes when exposed to fire retardant.

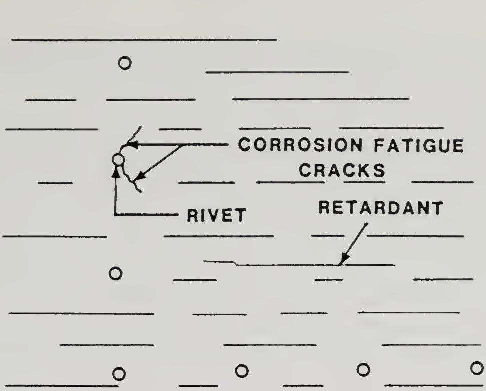


Figure 13.—Corrosion fatigue cracks on aluminum fuselage panel.

Figure 14.—Example of corrosion caused by a galvanic couple exposed to fire retardant.

METHODS OF CONTROLLING FIRE RETARDANT-CAUSED CORROSION

Materials Selection - Aircraft

Airframe.—Proper selection of materials for airtankers requires consideration of strength, weight, and corrosion characteristics. Because existing aircraft are usually adapted for airtanker service, airframe materials have already been selected. A choice of materials can be made, however, for replacement parts. The materials selected for replacement parts should be both compatible with existing airframe structural requirements and, if possible, resistant to corrosion by fire retardants. Selection of materials should be made considering the following:

1. Magnesium or other alloys known to be highly susceptible to retardant corrosion should be avoided.
2. Galvanizing (zinc coating) is not effective for protecting steel in fire retardants.
3. Cast aluminum is the best choice for wheels.
4. Type 304 stainless steel is the best choice for control cables.

Retardant Tank System.—Because the tank systems are fabricated and fitted specifically to carry retardant, materials and hardware can be selected for corrosion resistance. Use the following materials when possible:

1. Sidewalls, vents, stiffeners - 6061-T6 or 2024-T3 Alclad aluminum.
2. Actuator arms - 6061-T6 or 2024-T3 aluminum.
3. Torque tubes - 7075-T6 or 6061-T6 aluminum.
4. Metal hydraulic lines and fittings - aluminum.
5. Nuts and bolts - carbon or alloy steel for permanently mounted components, type 304 stainless steel for adjustable or removable components.
6. Hinges - type 304 stainless steel.
7. Rivets - aluminum alloy to match plate being joined.

Materials Selection - Ground Equipment

For ground equipment, use the following materials when possible:

1. Hose couplings - aluminum or plastic.
2. Valves - Austenitic 300 series stainless steel, coated steel, or plastic.
3. Pumps - all bronze, all aluminum, or plastic.
4. Mixing tanks - coated carbon steel.
5. Storage tanks - coated carbon steel, fiberglass or plastic lined.

Avoid dissimilar metal combinations, such as brass to aluminum hose couplings.

Inhibitor Additives

All formulated retardants approved under Forest Service specifications contain corrosion inhibitors. These retardants are formulated for a specific mix or use level. When properly mixed at this specified level, minimum corrosion should occur. Follow agency guidelines for field quality control assurance.

Protective Coatings

There are two basic categories of coatings—barrier coatings and metallic coatings. Barrier coatings protect the substrate metal by preventing contact with the electrolyte. If the barrier coating is damaged and the electrolyte penetrates to the substrate, corrosion will occur. Coatings formulated from polymeric resins such as alkyds, vinyls, epoxies, and polyurethanes are typical barrier-type coatings. Not all are equally effective in resisting fire retardants. For example, epoxy coatings are more resistant to fire retardants than alkyd-type coatings.

Metallic-type coatings protect metal by one or a combination of two ways. First, they prevent the fire retardant from contacting the surface that they are protecting and corrode at a slower rate than the metal they protect; second, they act as an anode and galvanically protect the underlying metal. Metallic coatings that act in both ways include zinc (galvanizing), aluminum, and cadmium. Nickel corrodes slowly, but does not protect galvanically. In fact, nickel would be cathodic to steel and, if there are breaks in the nickel coating, it will actually increase the rate at which steel corrodes, tending to cause rapid pitting of the steel at any breaks in the nickel coating. Galvanizing, however, is not effective for protecting steel in fire retardants.

Use of Protective Coatings on Airtankers.—The following provides guidance for using protecting coatings to control fire retardant corrosion on airtankers:

1. *Airframe.*—All magnesium components must be coated if they cannot be replaced with aluminum. A satisfactory coating system for magnesium includes a chromate wash primer, polyamide epoxy primer, and a polyurethane finish coat. No other airframe components, not coated originally, require protective coating.
2. *Tank and gating system.*—The tank and gating system on airtankers does not require a protective coating. The inhibitor additives in approved and properly mixed retardants are sufficient for corrosion control, assuming that the aircraft are cleaned regularly. The exception to this is magnesium. Uncoated magnesium components that cannot be practically replaced with an aluminum alloy should be coated in the same manner as specified for airframe parts.
3. *Use of grease-type preservative coatings.*—Regular maintenance of aircraft normally includes the use of protective grease-type preservatives and inhibiting compounds in corrosion-prone areas that are

not painted. These procedures should be followed on airtankers. For example, control cables should be periodically cleaned, inspected, and coated with a grease-type preservative coating. Normally inaccessible areas, such as tail sections, landing gear areas, and the front section of retardant tanks, should be cleaned, inspected, and coated with a thin-film corrosion-inhibiting compound. Commercial sources of these coatings include Black Bear Co. (Par-A1-Ketone), Aerospace Chemical Co. (Conquer), and Boeing Co. (BMS-3-23 or LPS-3).

Use of Protective Coatings on Ground Equipment.—Most of the ground mixing and handling equipment for fire retardants is steel. The steel equipment requires a protective coating for corrosion control. Specific recommendations for coating on ground equipment follow:

1. Exterior surfaces (storage tanks, mixing tanks, pumps, and other metal parts)—use polyamide epoxy.
2. Interior surfaces (storage tanks, mixing tanks)—use coal tar epoxy.

Table 1 lists commercial sources for the recommended coatings.

Surface Preparation and Application Requirements.—Adequate coating performance depends on proper surface preparation and application. Even excellent coatings have little chance of surviving if applied over corroded or peeling surfaces or over an incompatible paint. Manufacturers' specifications and procedures should be followed closely for good coating performance. A few of the most important points are discussed below.

1. *Cleaning the surface.*—Cleaning the metal is the most critical step in preparing the surface. If the surface has not been previously coated, sandblast the surface to a near-white surface (Steel Structures Painting Council Specification, SSPC-10). For recoating or touchup, power-tool clean or wire brush damaged areas. Cleaned surfaces must be free of moisture, rust, oil, grease, and small particles prior to primer application. Apply the primer as soon as possible after cleaning to prevent surface rerusting.
2. *Application.*—The recommended coatings are two-component epoxy systems. This type of coating has two components that must be mixed together in the exact proportions specified by the manufacturer. Neither component will cure by itself, but when the two are mixed together they will react chemically and harden. Curing takes time, but will take place even in the pot. Do not mix more coating than can be used during the pot life of the coating, usually 8 hours. Epoxy coatings usually will not cure well if ambient air temperature is below 50 °F. Allow sufficient cure time on interior tank coatings prior to filling the tank. Epoxy coatings are best applied using spray equipment, but brush application is acceptable.

Table 1.—Suppliers of retardant-resistant coatings

Coating	Supplier	No. of coats	Dry film thickness /coat	Surface preparation
			Mils	
Polyamine epoxy				
Carboline 188 primer intermediate finish (exterior only)	Carboline Co. 350 Hanley Industrial Court St. Louis, MO 63144	1 1 1	3 5 3	Commercial sandblast (SSPC-6) or power-tool clean
Mobil 78-D-7	Mobil Chem. Co. P.O. Box 250 Edison, NJ 08817	2	5-8	Near white (SSPC-10)
Koppers Dynacol	Koppers Co., Inc.			
210 primer	Grant Street	1	1.5-2	Near white
201HB topcoat	Pittsburgh, PA 15217	1	5-6	
Coal tar epoxy				
Carbomastic #3 primer	Carboline Co.	1	8	Near white
Carbomastic #14 topcoat		1	8	
Carbomastic #16		2	8	Near white
Tneme-Tar 413	Tnemec Co. 123 West 23d Ave. North Kansas City, MO 64116	2	8.3	Near white
Mobil 78-J-2	Mobil Chem. Co.	2	7	Near white
Koppers No. 300-M	Koppers Co.	2	10	Commercial sandblast (SSPC-6) or near white
Porter Super Tarset	Porter Paint Co. 400 So. 13th St. Louisville, KY 40201	2	8	Near white

Ventilation of Storage Tanks

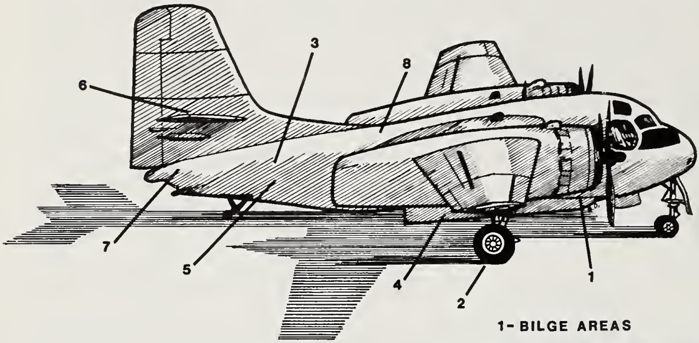
Storage tank ventilation reduces tank corrosion above the liquid/vapor phase interface. Design or modification that includes gravity ventilation or turbine ventilator-induced air flow will take away water vapor and ammonia fumes, reducing a major corrosion cause at low cost.

Maintenance

Adherence to a routine maintenance program prevents many corrosion problems and prolongs equipment life. An effective maintenance program includes frequent cleaning and inspection of equipment and coating repair.

Cleaning Aircraft.—Federal Aviation Administration Advisory Circular 43-4 and Airframe and Powerplant Mechanics General Handbook 69-5 describe effective cleaning and maintenance procedures for aircraft. The fuselage exterior, wings, landing gear, wheels, interior tail section, retardant tank vents, and tank require special attention regarding fire retardant accumulation and corrosion. Figure 15 shows these areas. Wash aircraft with approved detergent and water after

the completion of the day's missions. Care must be taken to rinse off the detergent with fresh water. Avoid brighteners for the wings and fuselage, as these will eventually lead to deterioration of Alclad surfaces. Thoroughly clean accumulated fire retardant from interior areas such as bilge areas, battery areas, and control cables. Clean the fire retardant tank with aircraft detergent and rinse with high-pressure water. Use aircraft detergents conforming to MIL-C-25769 (alkaline water base), MIL-D-6998 (methylene chloride), or MIL-C-43616.



1- BILGE AREAS
2- LANDING GEAR & WHEEL WELLS
3- CONTROL CABLES
4- FIRE RETARDANT TANK
5- RIVETED SKIN AREAS
6- HINGES
7- INTERIOR TAIL AREA
8- TANK VENTS

Figure 15.—Areas prone to corrosion on an airtanker.

Manufacturers of cleaning compounds are:

Amerace Corporation
Penetone Division
74 Hudson Avenue
Tenafly, NJ 07670

B&B Chemical Company
875 West 20th Street
Hialeah, FL 33010

Brulin & Company
P.O. Box 270-B
Indianapolis, IN 46206

Chemetron Corporation
Inorganic Chemicals Division
Cee-Bee Chemical
9250 East Cee-Bee Drive
Downey, CA 90241

Clarkson Laboratories, Inc.
1450 Ferry Avenue
Camden, NJ 08104

El Dorado Chemical Co.
P.O. Box 32101 (6700 Lookout Road)
San Antonio, TX 78216

Magnus Division
Economics Laboratory, Inc.
Osborn Building
St. Paul, MN 55102

McGean Chemical Company
9520 East Cee-Bee Drive
Downey, CA 90241

Oakite Products, Inc.
50 Valley Road
Berkley Heights, NJ 07922

Pennwalt Corporation
Metalprep Department
3 Parkway
Philadelphia, PA 19102

Turco Products
Division of Purex Corporation, Ltd.
24600 South Main Street
Carson, CA 90745

Wyandotte Chemicals Corporation
Wyandotte, MI 48193

Cleaning Ground Equipment.—Clean fire retardant spills from exterior surfaces as soon as possible after they occur. Use detergent and water. Thoroughly rinse the detergent from the surface with clear water. Flush mixing tanks, retardant hoses, pipes, pumps, and eductors with water after use. At the end of each fire season, clean the interior surfaces of storage tanks with detergent and water. Take care in selecting detergents. Avoid highly acidic or caustic detergents, those that produce excessive foaming, and those that contain enzymes. Final rinsing should be thorough, removing all traces of detergents. Residual detergent may adversely affect subsequent retardant solutions.

Inspection and Repair.—Inspect aircraft and ground equipment for corrosion at least twice each month. Repair serviceable components; replace those that are unserviceable. Clean and repair damaged coating. Remove all deteriorated and disbonded coating. Remove corrosion products and loose coating by power-tool cleaning the metal surface until clean, bright metal and firmly bonded coating remain. Conform to current FAA procedures when preparing coated aircraft surfaces. Prime the cleaned area with the primer originally used and topcoat with the original topcoat. It is important to use the same primer and topcoat for two reasons: first, the original coating will be

compatible with the new coating and they will bond together; second, the recommended coatings are known to be resistant to fire retardants.

An Example

Most of the above principles can be illustrated by the example of a common piece of equipment—a coupling in a hose that carries fire retardant. Assume that one part of the hose coupling is brass and the other half is aluminum (fig. 1). All the ingredients for corrosion exist:

1. *Galvanic corrosion.*—There are two different metals, one (aluminum) is the anode, the other (brass) is the cathode; there is an electrolyte (the fire retardant), which contacts both the anode and cathode; there is an electrical connection because the two halves of the coupling touch each other. An electric current will flow from the anode (aluminum) to the electrolyte (fire retardant); the aluminum will corrode. The current will flow through the fire retardant to the cathode (brass); the brass will not corrode. The current will then flow through the brass and aluminum (where they touch), completing the circuit.
2. *Local action corrosion.*—Fire retardants corrode both brass and aluminum even if the metals are not connected. Brass usually corrodes at a higher rate than aluminum. (Figure 2 illustrated local action corrosion.)

Corrosion of the coupling is rapid because it corrodes from both galvanic and local action. Now consider alternatives for stopping or reducing this corrosion:

1. Change the coupling materials. Both parts could be made from a common material, either brass or aluminum, to eliminate galvanic corrosion of the aluminum. Perhaps a plastic coupling could be substituted, thus eliminating corrosion altogether. If only aluminum or brass are feasible, the better choice would be aluminum because its local-action corrosion rate is less than that of brass.
2. Use a coating. The electrolyte could be prevented from touching either the aluminum or the brass, or both, by using a coating. If only one metal is coated, it would be better to coat the cathode (brass). If only the anode were coated, all of the corrosion current would flow through any coating pinholes. This would cause rapid and deep pitting.
3. Eliminate or change the electrolyte (fire retardant). Because the hose must carry fire retardant, the electrolyte cannot be eliminated. Strength, or chemical activity of the electrolyte, might be changed by adding chemicals. To be effective, such chemicals would have to reduce the difference in the charge on the surface of either the anode, cathode, or both. Also effective would be chemicals that formed an electrically insulating film on one or both surfaces, or a film that would keep the fire retardant from touching one or both surfaces.

The manufacturer must add such chemicals, called corrosion inhibitors, to all Forest Service-approved fire retardants to meet specific performance requirements.

4. Eliminate the electrical connection. It might be possible to insert a plastic bushing between the aluminum and brass. The nonconducting plastic would eliminate an electrical connection between the anode and cathode. Figure 16 shows this arrangement. Care would have to be taken to make sure there were no remaining electrical connections between the two coupling halves.

Any one of these choices would slow down the corrosion of the aluminum half of the coupling. With one of the four ingredients missing, corrosion stops, unless the retardant solution chemically attacks either the aluminum or brass.

Sometimes the insertion of a plastic bushing between the two halves of the coupling might not be practical. Perhaps, however, either the brass, aluminum, or both could be coated, say with an epoxy paint. Because only one of the ingredients must be eliminated, the inside of only one half of the coupling would have to be painted. Consider what would happen if paint were applied to the aluminum, and there were a small hole or perforation in the coating. Because the aluminum is the anode, all of the available current would have to flow through the small hole from a small area of the aluminum surface. All of the corrosion would tend to concentrate at this point, very rapidly eating a pinhole through the aluminum. Figure 17 illustrates this situation.

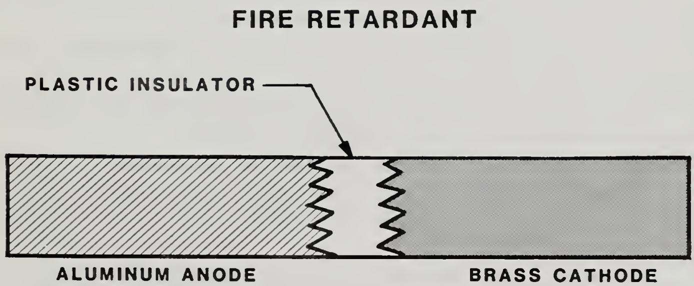


Figure 16.—The use of insulating material (plastic) to eliminate coupling between dissimilar metals.

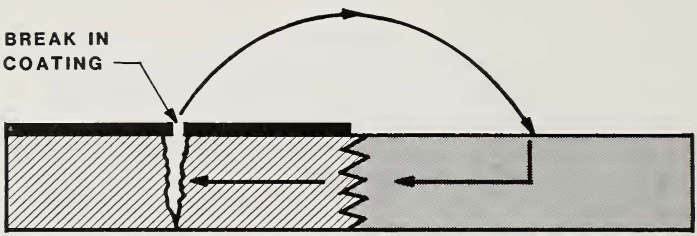


Figure 17.—Galvanic corrosion at perforation in a coating.

Summary

Control fire retardant corrosion by the following actions:

1. Select compatible, corrosion-resistant alloys when retrofitting surplus aircraft for airtanker service.
2. Do not use magnesium alloys. Apply a protective coating to all magnesium components that cannot be replaced.
3. Avoid joining dissimilar metals. If dissimilar metals must be used, separate them with nonmetallic materials, if this is possible.
4. Use only those retardant formulations containing effective corrosion inhibitor additives, meeting Forest Service specifications.
5. Use retardant formulations only at the recommended mix or use-level.
6. On aircraft, use protective grease-type preservatives and inhibiting compounds in unpainted, corrosion-prone areas.
7. Touch up damaged coating regularly. Strip and recoat aircraft when coating deterioration is extensive.
8. Use a protective coating on steel ground equipment. Provide structural ventilation for ground storage tanks.
9. Inspect aircraft and ground equipment for corrosion twice each month. Repair or replace corrosion-damaged components.
10. Rinse aircraft with plain water at least after each day's operations.
11. Thoroughly clean aircraft and ground equipment regularly. Use compatible detergents. Rinse thoroughly, removing all traces of detergent.

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Forest fire retardants can corrode aircraft and mixing, storage, and handling facilities. Extent and severity of corrosion depend on the metals involved, specific exposure, and other factors. This report provides a nontechnical description of the mechanics of such corrosion and how it can be prevented or minimized. Preventives include proper selection of materials, corrosion-inhibiting additives, protective coatings, ventilation of tanks, and proper maintenance.

KEYWORDS: fire retardants, corrosion, control, guidelines, exposure, alloys, aircraft inhibitor, protective coatings, ventilation, maintenance, quality control

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